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**APPLICATION FOR LETTERS PATENT**

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**Semiconductor Processing Methods of Removing  
Conductive Material**

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# Semiconductor Processing Methods of Removing Conductive Material

## TECHNICAL FIELD

The invention pertains to semiconductor processing methods of removing conductive material.

## BACKGROUND OF THE INVENTION

Conductive materials are frequently formed over semiconductive materials during fabrication of semiconductor chips. In typical processing, a circular wafer of semiconductive material is processed to have one or more thin conductive layers formed thereover. The conductive layers can comprise, for example, metal (such as, for example, copper, aluminum, titanium, tantalum, iron, silver, gold, etc.) or other conductive materials (such as, for example, conductively doped polysilicon). The conductive materials can be subsequently planarized by, for example, electrochemical-mechanical planarization. In electrochemical-mechanical planarization, the conductive material is exposed to an electrical circuit which causes at least some of the conductive material to be electrochemically removed and the material is simultaneously exposed to polishing conditions. The polishing conditions enhance removal of the conductive material and planarize a surface of any remaining conductive material. The polishing can be accomplished by, for example, abrasively removing the conductive material with a polishing pad and polishing slurry.

1 A difficulty associated with electrochemical-mechanical planarization  
2 processes can occur in attempting to maintain a circuit through a  
3 conductive material during a simultaneous electrochemical removal and  
4 polishing process. It is typical to utilize some portions of the conductive  
5 material for carrying current to other portions during the electrochemical  
6 removal. For instance, peripheral edges of the conductive material can  
7 be connected to a cathode terminal of a power source, a polishing pad  
8 connected to an anode terminal of the power source, and the conductive  
9 material utilized to complete a circuit between the anode and cathode  
10 terminals. A problem which can occur as portions of the conductive  
11 material are removed is that such can break an electrical connection to  
12 other portions of the conductive material. The breakage of the electrical  
13 connection can slow or stop electrochemical removal of such other  
14 portions of the conductive material.

15 In particularly problematic instances, some portions of conductive  
16 material will be entirely removed from around other portions of  
17 conductive material to leave such other portions as islands surrounded  
18 by electrically insulative materials. Such islands will thus have no  
19 electrical connection between the anode and cathode, and will not be  
20 subjected to electrochemical removal conditions. Accordingly, the removal  
21 of the islands will occur entirely through mechanical polishing and will  
22 be slowed relative to removal of conductive materials exposed to both  
23 electrochemical removal and mechanical polishing. Accordingly, there will

1 be non-homogeneous removal of conductive materials from over a surface  
2 of a wafer.

3 It would be desirable to develop methods of electrochemical  
4 removal that avoided some or all of the above-discussed problems.  
5

## 6 SUMMARY OF THE INVENTION

7 In one aspect, the invention encompasses a semiconductive  
8 processing method of electrochemical-mechanical removing at least some  
9 of a conductive material from over a surface of a semiconductor  
10 substrate. A cathode is provided at a first location of the wafer, and  
11 an anode is provided at a second location of the wafer. The conductive  
12 material is polished with a polishing pad polishing surface. The  
13 polishing occurs at a region of the conductive material and not at  
14 another region. The region where the polishing occurs is defined as a  
15 polishing operation location. The polishing operation location is  
16 displaced across the surface of the substrate from said second location  
17 of the substrate toward said first location of the substrate. The  
18 polishing operation location is not displaced from said first location  
19 toward said second location when the polishing operation location is  
20 between the first and second locations.

21 In another aspect, the invention encompasses a semiconductor  
22 processing method of removing at least some of a conductive material  
23 from over a surface of a semiconductive material wafer. A polishing pad

1 is displaced across an upper surface of the wafer from a central region  
2 of the wafer toward a periphery of the wafer, and is not displaced from  
3 the periphery to the central region.

4 In yet another aspect, the invention encompasses a method of  
5 electrochemically removing at least some of a conductive material from  
6 over a surface of a circular semiconductive material wafer which  
7 comprises radially displacing a polishing pad across the surface of the  
8 wafer. The radial displacing occurs only outwardly from a central region  
9 of the wafer and not inwardly toward the central region.  
10

#### 11 **BRIEF DESCRIPTION OF THE DRAWINGS**

12 Preferred embodiments of the invention are described below with  
13 reference to the following accompanying drawings.

14 Fig. 1 is a diagrammatic, fragmentary, cross-sectional sideview of  
15 an apparatus utilized in accordance with a method of the present  
16 invention.

17 Fig. 2 is a diagrammatic top view of a semiconductive material  
18 wafer processed in accordance with a method of the present invention.

19 Fig. 3 is a diagrammatic top view of a semiconductive material  
20 wafer processed in accordance with a method of the present invention  
21 and shown alternatively to the view of Fig. 2.  
22  
23

1           Fig. 4 is a diagrammatic, fragmentary, cross-sectional sideview of  
2 an apparatus utilized for processing a semiconductive material wafer in  
3 accordance with a second embodiment method of the present invention.  
4

#### 5       DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

6           This disclosure of the invention is submitted in furtherance of the  
7 constitutional purposes of the U.S. Patent Laws "to promote the progress  
8 of science and useful arts" (Article 1, Section 8).

9           A process of the present invention is described with reference to  
10 apparatus 10 of Fig. 1. Apparatus 10 comprises a support structure 12  
11 having a semiconductor substrate 14 supported thereby. Substrate 14 can  
12 comprise, for example, a monocrystalline silicon wafer. To aid in  
13 interpretation of the claims that follow, the terms "semiconductive  
14 substrate" and "semiconductor substrate" are defined to mean any  
15 construction comprising semiconductive material, including, but not limited  
16 to, bulk semiconductive materials such as a semiconductive wafer (either  
17 alone or in assemblies comprising other materials thereon), and  
18 semiconductive material layers (either alone or in assemblies comprising  
19 other materials). The term "substrate" refers to any supporting  
20 structure, including, but not limited to, the semiconductive substrates  
21 described above.

22           Substrate 14 has an upper surface 15. Such surface can comprise,  
23 for example, a surface of a semiconductive material wafer, or can

1 comprise a surface of a material formed over a semiconductive material  
2 wafer. For instance, surface 15 can comprise a surface of an insulative  
3 material formed over a stack of circuit devices associated with a  
4 semiconductive material wafer.

5 A conductive material 16 is formed over upper surface 15 of  
6 substrate 14. Conductive material 16 can comprise, for example, a metal  
7 and/or conductively-doped silicon.

8 Substrate 14 has an outer peripheral edge 18 and a central inner  
9 region 20. A polishing pad 22 is provided over central region 20 of  
10 substrate 14. Polishing pad 22 is sized to extend over only a central  
11 portion of conductive material 16, and to leave peripheral portions  
12 uncovered. Polishing pad 22 is supported by a support structure 24  
13 which is configured to enable rotation of pad 22 about an axis "Y".

14 Electrical connections 26 are provided along outer periphery 18 of  
15 substrate 14 and electrically contact conductive material 16. Electrical  
16 connections 26 are connected to a power source 28 which is also  
17 connected to polishing pad 22. Power source 28 forms a circuit which  
18 extends between polishing pad 22 and electrical connections 26 through  
19 conductive material 16, and which utilizes polishing pad 22 as an anode  
20 and connections 26 as a cathode. An electrolytic bath 30 is provided  
21 over conductive material 16 and between polishing bath 22 and electrical  
22 connections 26 to complete the electrical circuit. Electrolytic bath 30  
23 can comprise, for example, an aqueous solution having salts dissolved

1 therein. Bath 30 can also comprises abrasive particles for utilization as  
2 polishing slurry during polishing of conductive material 16 with polishing  
3 pad 22.

4 Although the embodiment of Fig. 1 shows electrolyte as being  
5 provided by a bath 30, it is to be understood that the electrolyte can  
6 be provided only over surface 16 by, for example, flowing a stream of  
7 electrolyte onto surface 16. Such stream could be flowed, for example,  
8 through a porous polishing pad 22, or alternatively through a tube  
9 provided over surface 16 and configured to allow the electrolyte to flow  
10 across surface 16 and under pad 22. Also, a polishing slurry could be  
11 provided by flowing a stream of slurry over surface 16, rather than as  
12 material within a bath.

13 Support 12 is configured to spin about an axis "Z" and to thereby  
14 spin substrate 14 and conductive material 16 relative to polishing pad 22.  
15 Polishing pad 22 comprises a surface 32 configured to abrasively remove  
16 material 16 as the surface is moved relative to material 16. In  
17 particular embodiments, the abrasive action of surface 32 results from  
18 interaction of surface 32 on a polishing slurry. In other embodiments,  
19 the abrasive action results from contact of surface 32 directly against  
20 material 16. Regardless of whether surface 32 contacts material 16  
21 directly and/or through a polishing slurry, the spinning of material 16  
22 relative to polishing pad 22 creates an abrasive action on material 16  
23 which causes removal of at least some of material 16. Since polishing



1 pad 22 is sized to extend over only a portion of conductive material 16,  
2 polishing surface 32 has a smaller surface area than does material 16.

3 Although both pad 22 and substrate 14 are shown being rotated,  
4 it is to be understood that the invention encompasses other embodiments  
5 wherein only one of pad 22 and substrate 14 is rotated. Also, although  
6 pad 22 is shown being rotated in a counter-rotary manner relative to the  
7 rotation of substrate 14, it is to be understood that the invention  
8 encompasses other embodiments wherein the pad and substrate rotate in  
9 a common direction relative to one another.

10 An electric current is provided within material 16 from power  
11 source 28 during the polishing of the material with pad 22. Such  
12 electric current causes electrochemical removal of conductive material 16,  
13 and thus enhances removal of material 16 relative to the removal which  
14 would occur by polishing action alone.

15 After at least some of conductive material 16 is removed from  
16 over central region 20 of substrate 14, pad 22 is displaced outwardly in  
17 direction "W" relative to substrate 14. Cathode 26 can be considered  
18 as being at a first location of substrate 14 and central region 20 can be  
19 considered a second location of substrate 14, and the displacement of  
20 pad 22 along direction "W" can thus be considered a movement of  
21 polishing surface 32 from the first location of substrate 14 toward the  
22 second location. Preferably, polishing pad 22 is displaced only from the  
23 second location toward the first location, and not in the reverse

1 direction. In such preferred embodiment, conductive material 16 is  
2 removed from over a central location of substrate 14 prior to removing  
3 the conductive material from over outer regions of substrate 14. Thus,  
4 a circuit extending between cathode 26 and the anode of pad 22 through  
5 conductive material 16 can remain complete during removal of the  
6 conductive material 16. Specifically, since the inner (i.e., more central)  
7 portions of conductive material 16 are removed prior to removing outer  
8 portions of conductive material 16, and since pad 22 is not moved back  
9 over a more central region of conductive material 16 after removing an  
10 outer region of conductive material 16, a bridge of conductive  
11 material 16 can always remain between pad surface 32 and cathode 26  
12 to maintain electrical conductivity between cathode 26 and pad surface 32  
13 during removal of conductive material 16. Such can alleviate prior art  
14 problems discussed above in the "Background" section of this disclosure.

15 It is noted that although cathode 26 is shown at an outer  
16 periphery of substrate 14 and the anode is shown starting at a central  
17 region of substrate 14, the relative positions of the cathode and anode  
18 can be reversed. Also, it is noted that cathode 26 can be a single  
19 electrode extending entirely around a periphery of substrate 14, or can  
20 comprise a plurality of electrode segments spaced around periphery 18  
21 of substrate 14. It is additionally noted that although polishing pad 22  
22 is shown starting at a central location of substrate 14, it is to be  
23 understood that the polishing pad could start at a different location of

1 substrate 14, provided that in a preferred embodiment the pad worked  
2 from the starting location toward the cathode, and was not worked back  
3 toward the starting location after it had left the starting location.

4 Fig. 2 shows a top view of substrate 14, and shows electrode 26  
5 as a continuous electrode extending around substrate 14. Fig. 2 also  
6 shows an exemplary path 40 for polishing pad 22 (Fig. 1). The pad  
7 starts at about central region 20 and spirals outwardly from central  
8 region 20 toward periphery 18 of substrate 14. The shown substrate 14  
9 is circular and has radii 42 extending outwardly from a central location.  
10 The spiral path of the polishing pad moves the pad only outwardly along  
11 radii 42, and not inwardly. In other words, the polishing pad is moved  
12 only from central location 20 outwardly toward periphery 18, and not  
13 inwardly back toward central location 20. A term "polishing operation  
14 location" is utilized in this document to refer to locations wherein  
15 polishing is actively occurring. The movement of polishing pad 22 moves  
16 the polishing operation locations across substrate 14 in the spiral  
17 pattern 40.

18 Direction "W" of Fig. 1 is shown in Fig. 2 to illustrate that the  
19 spiral path 40 causes the polishing pad to be always moving outward  
20 from central location 20 toward a point 44 on periphery 18 along  
21 direction "W" whenever the pad is between central location 20 and the  
22 location corresponding to point 44. It is also noted that when polishing  
23 pad 22 is not between location 20 and point 44, the pad does not move

1 along direction "W", but instead moves in other directions which take  
2 the pad outwardly from central location 20 toward periphery 18. It is  
3 further noted that the spiral trajectory of path 40 defines concentric  
4 rings of travel of the polishing pad, with such concentric rings extending  
5 radially outward from central location 20.

6 The spiral pattern of Fig. 2 is but one pattern which can be  
7 utilized to progress polishing operation locations across a substrate  
8 surface. Another pattern which could be utilized is in the form of  
9 distinct rings 60, 62 and 64 shown in Fig. 3. Note that the more  
10 centrally occurring ring 60 would preferably be formed first, followed by  
11 ring 62, and lastly by the most outward ring 64. Note also that the  
12 polishing pad could remain in abrasive contact with a surface of  
13 conductive material 16 as the pad moves from one ring to another, or  
14 alternatively that the pad could be lifted from conductive material 16  
15 during movement of the pad from one ring to another.

16 As was discussed above with reference to Fig. 1, one or both of  
17 a polishing pad and a wafer substrate can be rotated during displacement  
18 of the pad relative to the wafer substrate. It is to be understood that  
19 rotation of either the pad or the substrate is not the same as  
20 "displacement" within the present application. Specifically, the term  
21 "displacement" is defined to refer only to situations in which a polishing  
22 operation location is moved across a wafer surface, and not to situations  
23 wherein a polishing operation location remains at a same location over

1 a wafer surface while a pad is being rotated or otherwise mechanically  
2 agitated. Also, it is to be understood that displacement can occur by  
3 moving either a substrate, a polishing pad, or both a substrate and a  
4 polishing pad, provided that the net result is movement of the substrate  
5 and/or pad relative to the other of the substrate and/or pad. Further,  
6 it is to be understood that displacement can occur without moving a  
7 polishing pad relative to a substrate, provided that a location of a  
8 polishing operation is moved relative to the substrate.

9 An exemplary apparatus in which a polishing operation location is  
10 displaced without displacement of a polishing pad is described with  
11 reference to Fig. 4. In referring to Fig. 4, similar numbering will be  
12 used as was utilized above in describing the apparatus of Fig. 1, with  
13 the suffix "a" used to indicate structures shown in Fig. 4.

14 Fig. 4 shows an apparatus 10a comprising a substrate holder 12a  
15 and a substrate 14a supported by holder 12a. A conductive material 16a  
16 is formed over substrate 14a and extends across an upper surface of  
17 substrate 14a. Substrate 14a has a central region 20a and a peripheral  
18 region 18a, and comprises at least one electrode 26a connected to  
19 conductive material 16a along periphery 18a. A flexible-material  
20 polishing pad 22a is provided over conductive material 16a. A narrow  
21 structure 24a (shown as a post) is provided over a location of pad 22a  
22 and pushes a region of pad 22a against conductive material 16a.  
23

1 Pad 22a is electrically connected to a power source 28a, which in turn  
2 is connected to electrode 26a.

3 In operation, post 24a is utilized to press a portion of large  
4 pad 22a against a region of conductive material 26a, and subsequently  
5 substrate 14a is rotated relative to pad 22a to cause abrasion of  
6 material 26a in a location pressed against pad 22a. Also, power  
7 source 28a is utilized to provide current through conductive material 16a  
8 during rotation of substrate 14a, and thus to facilitate electrochemical  
9 removal of material 16a in conjunction with the abrasive polishing.

10 Pad 22a can be supported by post 24a such that the pad and post  
11 are moved over conductive material 16a in, for example, a spiral pattern  
12 similar to that shown in Fig. 2. Alternatively, pad 22a can be separately  
13 supported so that the pad remains in a fixed location and post 24a is  
14 displaced over the pad to cause different portions of the pad to be  
15 pushed against spinning substrate 14a. Post 24a could be moved, for  
16 example, in a spiral pattern such as that shown in Fig. 2. In  
17 embodiments in which pad 22a remains stationary during the movement  
18 of post 24a, a location of a polishing operation is displaced relative to  
19 substrate 14a by displacement of post 24a, and without displacement of  
20 polishing pad 22a. The peripheral edges of pad 22a are shown raised  
21 relative to the center of pad 22a. Such configuration can be achieved  
22 by utilizing a pad material having an inherent flex of its peripheral  
23 edges relative to its center region, or by attaching one or more support

1 structures (not shown) to the peripheral edges of the pad to raise the  
2 edges. Alternatively, the pad can be formed of a flexible material which  
3 lays flat across surface 16a, but which is in non-abrasive contact with the  
4 surface in regions which are not pressed between post 24a and  
5 surface 16a.

6 It is noted that in the above-described embodiments of Figs. 1  
7 and 4 only a portion of conductive material 16 is exposed to abrasive  
8 polishing at any given time during an electrochemical polishing process.  
9 Accordingly, some portions of a conductive material (16 or 16a) are in  
10 abrasive contact with a polishing pad (22 or 22a), and other portions are  
11 not in such abrasive contact during an electrochemical polishing process.  
12 As the polishing process progresses, the portions which had not been in  
13 abrasive contact become in abrasive contact while the portions that had  
14 been in abrasive contact are no longer in abrasive contact with the  
15 polishing pad. Preferably, once a portion progresses from being in  
16 abrasive contact with a polishing pad to not being in abrasive contact  
17 with the polishing pad, it is no longer exposed to electrochemical  
18 polishing conditions during the remainder of the electrochemical polishing  
19 process.

20 The above-described electrochemical polishing processes can be  
21 followed by conventional chemical-mechanical polishing processes to buff  
22 a substrate after the electrochemical polishing. The chemical-mechanical  
23

1 polishing comprises polishing with a polishing pad and slurry, and is not  
2 electrochemical polishing.

3 In compliance with the statute, the invention has been described  
4 in language more or less specific as to structural and methodical  
5 features. It is to be understood, however, that the invention is not  
6 limited to the specific features shown and described, since the means  
7 herein disclosed comprise preferred forms of putting the invention into  
8 effect. The invention is, therefore, claimed in any of its forms or  
9 modifications within the proper scope of the appended claims  
10 appropriately interpreted in accordance with the doctrine of equivalents.  
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